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EUROPEAN COOPERATION IN THE FIELD OF SPACE RESEARCH AND AEROSPACE ENGINEERING

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A general view is given over the organization, structure, and activity of the European Space Research Organization (ESRO) and European Launcher Development Organization (ELDO), in combination with the activity of the individual member nations. Launch facilities, data processing centers, and the various versions of the launch vehicles (ELDO-B1, B2, Europa I, etc.) are described, with photographs, graphs, and block diagrams of the units and launch facilities. Cooperation with the USA in communications satellites and other peaceful application of unmanned space vehicles is outlined, including a brief review of future plasma propulsive systems.

1. Development of Space Research

The eternal search of man to discover the laws governing the events in cosmic space is ancient. The classical discipline of science which had been concerned with this task for many centuries is astronomy. Until about 30 years

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** Department for Aerospace Engineering of the Polytechnic Institute Darmstadt, President of the Council of the European Launcher Development Organization (ELDO).

*** Numbers in the margin indicate pagination in the original foreign text.

ago, the work of astronomers was exclusively based on observations in the visible spectrum region. A new possibility was created in 1931 by the discovery that also radio waves, in the short-wave range at lengths of a few millimeters to about ten meters, coming from space, reach the earth's surface. This discovery led to the development of radioastronomy; the methods of this discipline are based on the experience gained in radar engineering which, specifically in Europe, was developed during World War II. All other wave ranges - from the long-wave radio waves to the wavelengths of X-radiation and corpuscular radiation - cannot be observed from the earth's surface, since these radiations are not passed by the earth's atmosphere. Therefore, a decisive step forward was obtained in astronomy when the USA, in 1946, was successful in recording an ultraviolet spectrum of the sun by means of a V-2 rocket. The International Geophysical Year 1957/58 then brought the first data collected by satellites, launched by the Soviet Union and the USA. Since that time, high-altitude sounding rockets, earth satellites, and space probes have become indispensable aids for the research work of astronomists, geophysicists, and also meteorologists, without which successful activity in these fields of science is no longer possible. The practical application of these modern research methods was originally restricted to the USA and the Soviet Union.

2. The European Space Research Organization (ESRO)

To give European scientists a possibility of utilizing the methods of space research for their own work, a number of European nations signed an agreement in 1961 on the creation of a preparatory European Commission for Space Research. Subsequently, after ratification of the agreement in spring 1964 by the parliaments of the individual nations, the European Space Research Organization (ESRO) was set up. This organization, at present, comprises Belgium, Federal Republic of Germany, Denmark, France, Great Britain, Holland, Italy, Sweden, Switzerland, and Spain.

2.1 Structure of the ESRO

The chartered purpose of the ESRO is to promote cooperation between the European nations in the field of space research and to make available to European researchers all necessary scientific and technical facilities. A list of the Centers and Institutes, created within the ESRO for this purpose, is given in Table 1.

TABLE 1

CENTERS OF THE EUROPEAN SPACE RESEARCH ORGANIZATION (ESRO)

Name of Institute	Abbreviation	Location
European Space Technology Center	ESTEC	Noordwijk, Holland
European Space Laboratory	ESLAB	Noordwijk, Holland
European Space Data Center	ESDAC	Darmstadt, Federal Republic Germany
European Space Research Institute	ESRIN	Rome, Italy
European Space Launching Range	ESRANGE	Kiruna, Sweden

The European Space Technology Center (ESTEC) is being erected in Noordwijk, Holland. Here, the satellites and the nose cones of the high-altitude sounding rockets and space probes will be assembled and tested, together with the total installation of measuring instruments, electric equipment, and other instrumentation, under launch conditions, ascent, and stay in space. For this, extensive laboratories and a large staff of scientists and engineers are required which, together with the necessary assistant personnel, will finally consist of 800 - 1000 members. In addition, the European Space Laboratory (ESLAB) will be constructed in Noordwijk. This is planned as a small scientific research institute. Here, scientists from the member nations of the ESRO are given an opportunity, for a limited time and on a fellowship basis, to work on projects for which the necessary facilities are not available in their own country and for /3 which the closeness of the ESTEC is highly valuable. For processing the data, obtained from tracking of satellite orbits and from the instrumentation of the satellites, the European Space Data Center (ESDAC) is being erected in Darmstadt, which is to be directly linked with several of the satellite and space-probe tracking stations and which will be equipped with high-speed electronic computers. The European Space Research Institute (ESRIN), under construction in Rome, is to permit laboratory experiments, as a counterpart to the data obtained from sounding rockets or satellites, concerning - for example - the particle interaction or the behavior of low-density plasma. For this Institute, a personnel

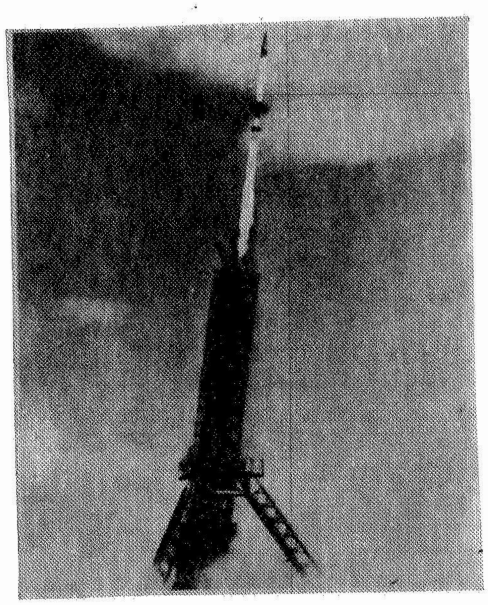

Fig.1 Sounding Rocket "Skylark" (BAC/RAE)
L = 7.60 m, G = 1150 kg.

of about 80 persons, including approximately 25 scientists, is planned. Finally, there is the European Space Launching Range (ESRANGE), being built in Kiruna in Northern Sweden. This facility is to be used for launching of high-altitude sounding rockets, specifically for investigating auroral phenomena; the first launchings are scheduled for 1966.

2.2 Work Program of the ESRO

Within the work program of the ESRO, priority is given to data collection by sounding rockets, since experiments of this type do not require such protracted preparations as for satellites. The research projects, for which the

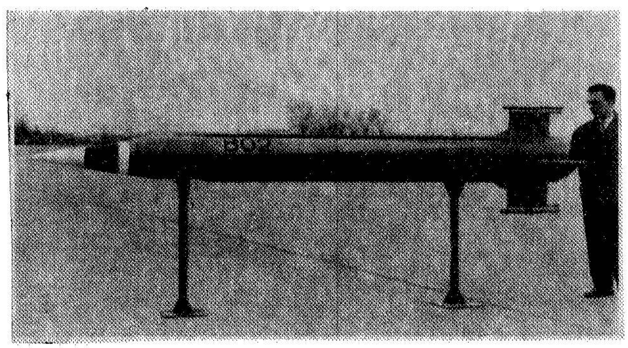

Fig.2 Sounding Rocket "Bélier" (Sud-Aviation)
L = 4 m, G = 313 kg.

ascents of high-altitude probes are intended, include - for example - detection of air currents in the upper layers of the atmosphere, measurements within the ionosphere, observations of auroras, photometry and spectroscopy of the sun and stars, measurement of solar X-ray radiation, and measurements of cosmic radiation. In 1964, three sounding rockets of this type were successfully launched; for 1965, seven launchings and, for 1966, about 20 launchings are scheduled. As sounding rockets, the prototypes "Skylark", "Bélier", "Centaure", and "Arcas" will be used. The "Skylark" (Fig.1) was developed by the Royal Aircraft Establishment in Farnborough; this rocket is able to lift a payload of 90 kg to an altitude of 200 km. The rocket "Bélier" (Fig.2), built by the Sud-Aviation, is intended for small payloads (30 kg) and low altitudes (85 km). This rocket serves simultaneously as the upper stage for the "Centaure" (Fig.3) which carries a payload of 30 - 60 kg to altitudes of 180 - 130 km. The "Arcas" is a product of the Atlantic Research Corporation in the USA, with a payload of 5.4 kg and an altitude of 65 km. All these rockets are of the unguided type and

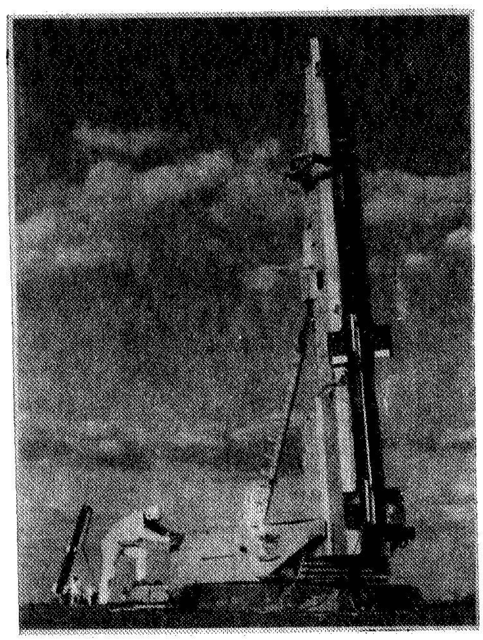

Fig.3 Sounding Rocket "Centaure" (Sud-Aviation)
L = 6 m, G = 460 - 490 kg.

fall back to earth after reaching their ceiling. Therefore, they can be launched only from bases in whose vicinity the spent rockets can impact without hazard to personnel or equipment. In addition to Kiruna in Northern Sweden, especially Sardinia, Andoya (Norway), and the Ile du Levant (Mediterranean) have been scheduled as launching bases. Naturally, it would be desirable to be able to start such rockets also in regions that are more densely settled. However, for this it would be necessary to decompose the rockets, after burnout, into such small parts that they can create no damage on return to earth or by guiding the probe, after burnout of the rocket, back to earth. The development of recoverable high-altitude probes has been successfully initiated at various facilities, with satisfactory promise of success. A typical example is the version suggested by the German Dornier Co., which uses a paraglider for recovering the

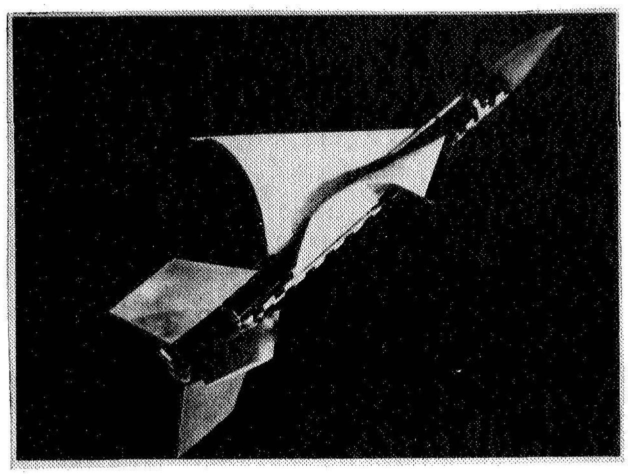

Fig.4 Proposal of a Recoverable High-Altitude Research Rocket (Dornier System GmbH)

rocket (Fig.4). The spent rocket shell constitutes the center spar of the paraglider. The side spars and the flexible skin are housed within the body of the rocket, in the folded state, during ascent. On descent of the rocket, the paraglider is deployed and will permit return of the rocket to its launching site by remote control. /4

In addition to the high-altitude probes, also satellites will be launched within the ESRO program after 1967. The satellites, presently scheduled by the ESRO, are compiled in Table 2. The Table also contains the launch-vehicle systems which will place the satellites in orbit, together with the date of the presumable first launching of the corresponding satellite series.

TABLE 2

SATELLITE PROGRAM OF THE ESRO

Satellite	Abbreviation	Launch Vehicle	First Launching
1. Small satellites			
ESRO I	S1	Scout	1967
ESRO II	S2	Scout	1967
2. Medium stabilized satellites (Thor-Delta satellites)	TD	Thor-Delta	1969
3. Satellites with highly eccentric orbit	SP	Thor-Delta	1969 (?)
4. Large astronomic satellites	A	Europa I	1970 (?)

The satellite "ESRO I", which is scheduled for launching in Fall of 1967, will have a weight of about 90 kg. Its instrumentation is to measure the flux and energy spectrum of ions, electrons, and protons in the upper atmosphere, including electron temperature and density within the ionosphere, and to perform photometry of the auroral zone. For this, an eccentric polar orbit, with a perigee of 275 km and an apogee of 1500 km has been selected for the satellite; the orbit is to be laid out such that the satellite will remain as long as possible in the northern polar zone and in the shadow of the earth. The satellite is to be magnetically stabilized.

For the satellite "ESRO II", measurements of solar and cosmic radiation as well as of protons trapped in the earth's magnetic field, are in the foreground of interest. Weight and orbital configuration of the ESRO II were selected similar to those of the ESRO I, except that the orbit was laid out for a maximum stay of the satellite in sunlight.

The medium satellites will have a weight up to 500 kg and a circular orbit of about 500 km height. Among others, they are intended for measurements of solar X-ray radiation, spectroscopic investigations of celestial light in the infrared and ultraviolet regions, observations of zodiacal light, measurements of gamma radiation and of cosmic particle radiation. The satellites will be stabilized to a fixed position in space.

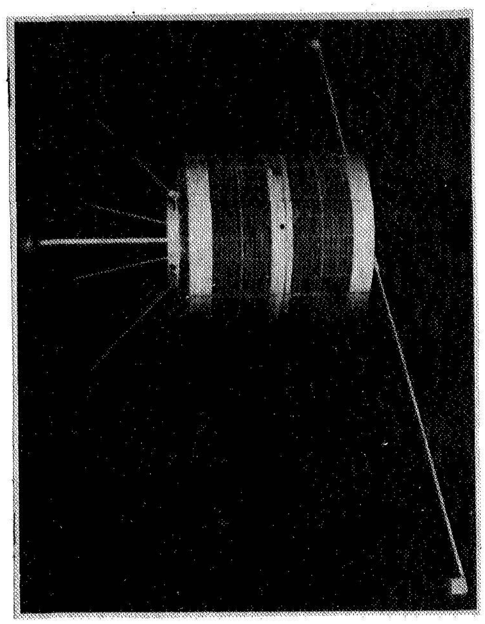

Fig.5 Satellite "ESRO I" (Laboratoire Centrale de Télécommunications)

The main purpose of the large astronomic satellites is to obtain spectra of stars in the 900 - 3000 Å region, with a resolution of at least 1 Å. In addition, the instrumentation will include a broad-band recorder for X-ray radiation and a gamma-ray telescope. The weight of the satellite is scheduled as about 800 kg. The satellite is to be inserted into a circular orbit of about 700 km.

The accompanying photographs are to give an idea as to the satellites described in this paper.

As a first example of the satellite series of the ESRO, Fig.5 shows a model of the ESRO I satellite, for which the Laboratoire Centrale de Télécommunications (Central Laboratory for Telecommunications) is the prime contractor. The solar cells for generating electric power required for operating the instruments are mounted to the periphery of the satellite. The sphere, attached to a centrally mounted rod, contains the testing equipment for analyzing the ions in the space traversed by the satellite. The ends of the two cantilevers carry the equipment for measuring density and temperature of the ions. All other instrumentation is housed within the satellite. The four antennas protruding from the top serve for telemetry.

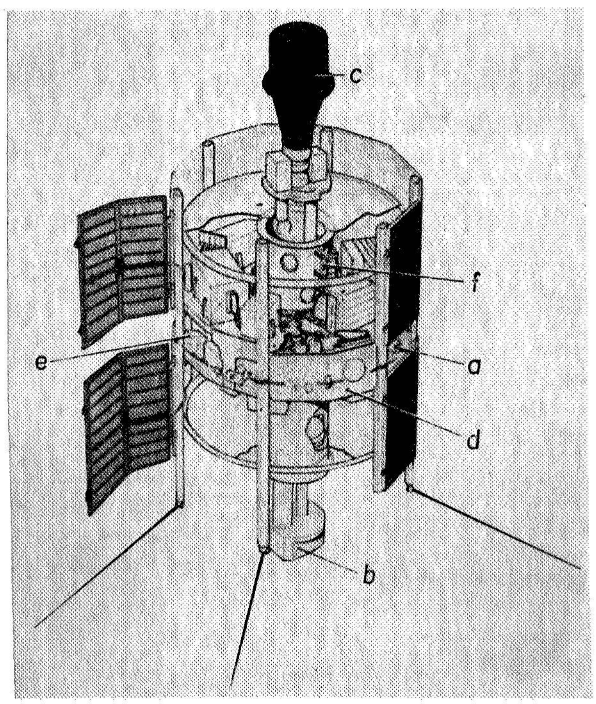

Fig.6 Satellite "ESRO II" (Hawker Siddeley Dynamics, Ltd.) Experimental task: a = protons in the Van Allen belt; b and c = cosmic radiation; d and e = solar X-ray radiation; f = energy spectrum of solar protons.

For the satellite ESRO II, shown in cross section in Fig.6, the Hawker Siddeley Dynamics is the prime contractor. The instrumentation, sketched in this diagram, is to measure the following: /5

a) protons in the Van Allen belt;

b) and c) cosmic radiation, specifically intensity of protons and alpha particles as well as primary radiation flux;

d) and e) solar X-ray radiation;

f) flux and energy spectrum of solar protons.

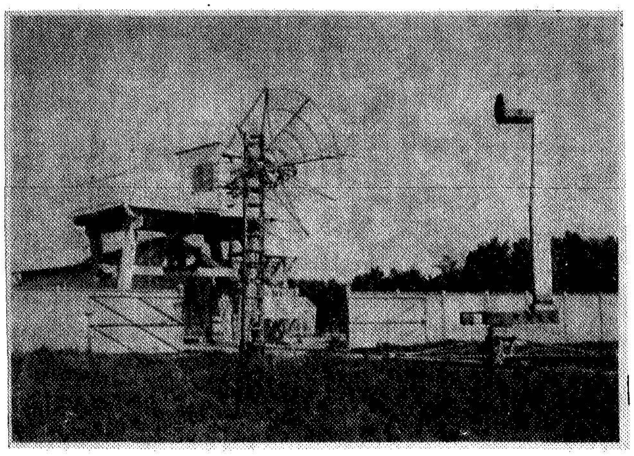

Fig.7 "ESRO II" during the Antenna Test (Hawker Siddeley Dynamics, Ltd.).

Figure 7 shows the ESRO II satellite during the antenna test, in which the transmitting and receiving characteristics of the antennas are tested.

The other satellites scheduled by the ESRO are still in the projection stage. A projection study for the large astronomic satellite is shown in Fig.8.

Other large-scale projects of the ESRO, even including possible exploration of the moon, are under discussion at present.

As launch vehicles for the first satellites, the American Scout rocket has been selected. The large astronomic satellite is to be started with the "Europa I", being developed within the European Launcher Development Organization (ELDO).

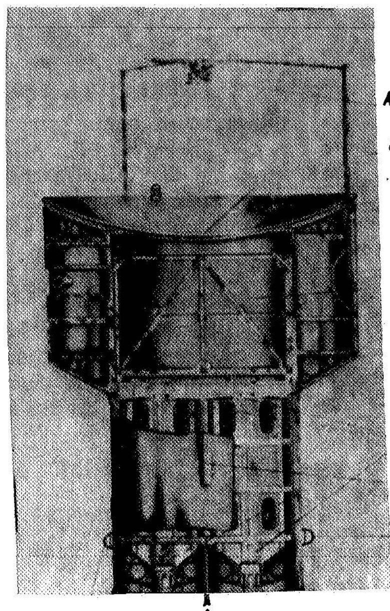

Fig.8 Astronomic Satellites for ESRO
(Project DVL - Bölkow GmbH)

3. <u>The European Launcher Development Organization (ELDO)</u>

The function of the ELDO is to develop and construct a spacecraft booster suitable for inserting satellites into orbit or for carrying space vehicles into cosmic space. Manned space flights were intentionally excluded from the program for the time being.

The convention for organizing the ELDO was signed in spring of 1962 by the governments of Great Britain, France, German Federal Republic, Italy, Belgium, Holland, and Australia. After the parliaments of all nations, with the exception of Italy, had ratified the agreements up to beginning of 1964, the convention went into force in May 1964. In the meantime, Italy also has ratified the agreement.

In contrast to the ESRO, the ELDO does not have its own Centers or Institutes. The structural elements of the launch vehicle are developed and constructed in the individual member nations. The work is coordinated by the General Secretariat of the ELDO which has its headquarters in Paris and whose staff, at present, comprises about 200 persons.

3.1 Initial Program of the ELDO

The starting point for spacecraft boosters of the initial program is the first stage; for this, the "Blue Streak" rocket, manufactured in Great Britain, is used. The second stage is being developed on the basis of practical experience with the "Véronique" series in France. The development and construction /6 of the third stage has been entrusted to the Federal Republic Germany.

The all-up weight of the launch vehicle on liftoff is determined by the thrust delivered by the engines of the first stage. This thrust, in the "Blue Streak", is produced by two rocket engines and is 136 tons. Accordingly, the

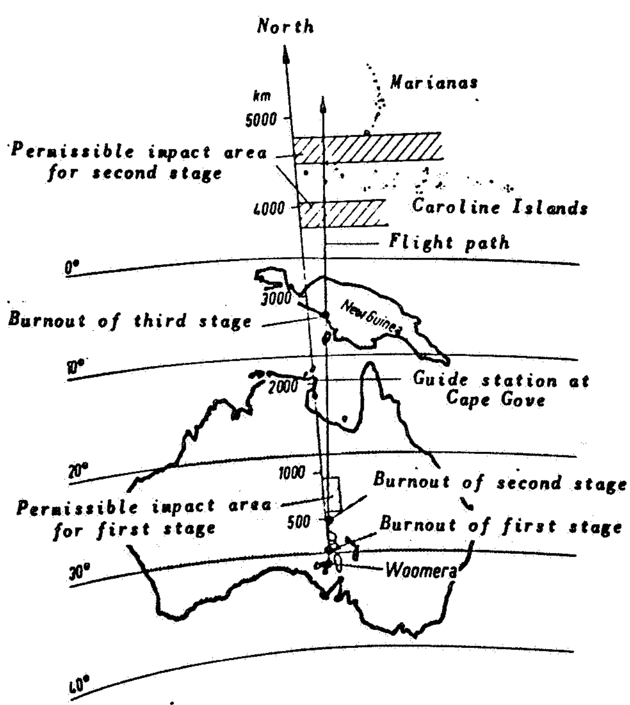

Fig.9 Launch Site for ELDO Spacecraft Boosters in Woomera, Australia

blastoff weight of the European spacecraft boosters has been set at 105 tons. As launching site for the system, Woomera in Southern Australia was selected (Fig.9). The central part of Australia has large uninhabited regions, so that

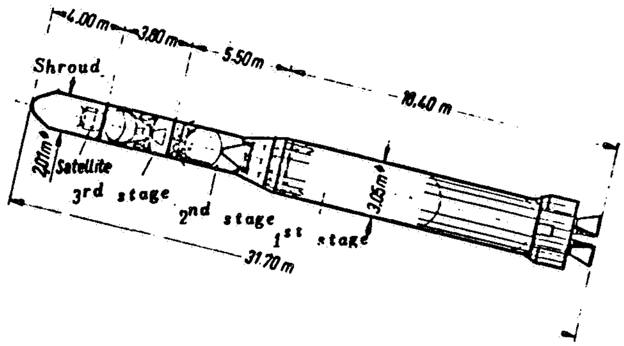

Fig.10 Launch Vehicle of the ELDO

	Weight on Liftoff (tons)	Thrust (tons)
First stage	88.3 to 90	136
Second stage	11.5	28
Third stage	3.3	2.25
Satellite	0.2 to 1.2	
Total	105	

a landing of the spent first stage can be tolerated there. The spent second stage, depending on the selected orbit, presumably will splash down in the ocean North of Australia.

The most favorable subdivision of the rocket system over the individual stages was obtained by optimizing. Such calculations allow for the propellants of the individual stages and the type of engines used. In addition, the above-mentioned permissible impact areas for the spent first and second stage must be taken into consideration. The optimizing was done for a circular orbit of a satellite at 550 km altitude above the earth and led to the subdivision shown in Fig.10. Accordingly, the first stage on blastoff will have a weight of 88.3 tons, i.e., about 85% of the all-up weight; the second stage of 11.5 tons constitutes 11% of the total weight; the third stage, weighing 3.3 tons, comprises approximately 3% of the total weight. For the satellite itself, the remaining available weight will presumably be 600 - 800 kg for an orbit of 550 km height.

The first stage is powered by two engines of 68 tons thrust each, constructed by Rolls Royce. A schematic diagram of the entire power plant system is shown in Fig.11. As fuel, kerosene is used and, as oxidizer, liquid oxygen (LOX), carried in the tanks shown in the upper portion of the diagram. Before

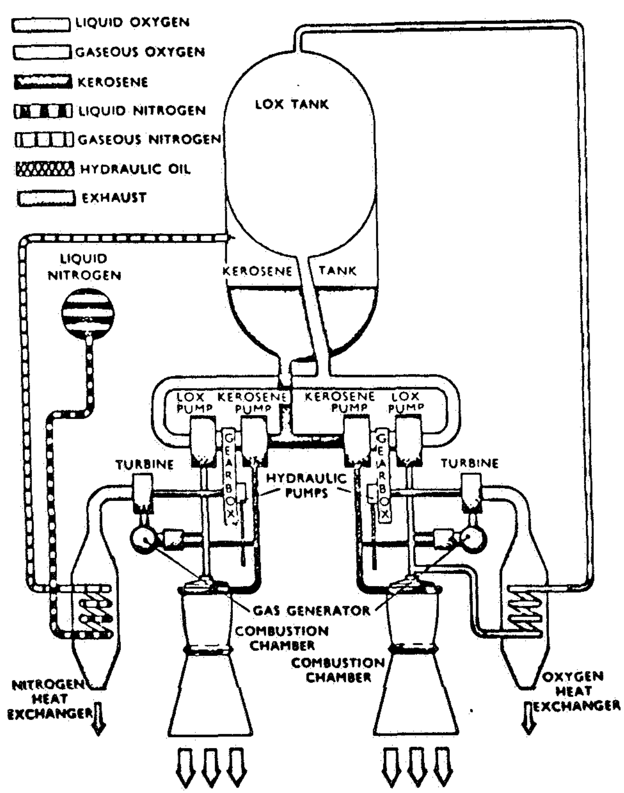

Fig.11 Power Plant System for the First Stage of the ELDO Launch Vehicle

liftoff, the pressure in the tanks is built up by ground equipment. After liftoff, pumps take over the propellant feed to the engines. The engines are driven by turbines whose working medium is produced in gas generators from the same propellants on which the main engines are operated. The turbines also drive the hydraulic pumps that furnish the pressure for operating the actuating cylinders for swiveling the engines. Adequate pressure in the tanks after liftoff is maintained by vaporization of nitrogen or oxygen; the evaporation takes place in heat exchangers, supplied with heat from the hot exhaust gases of the turbines. /7

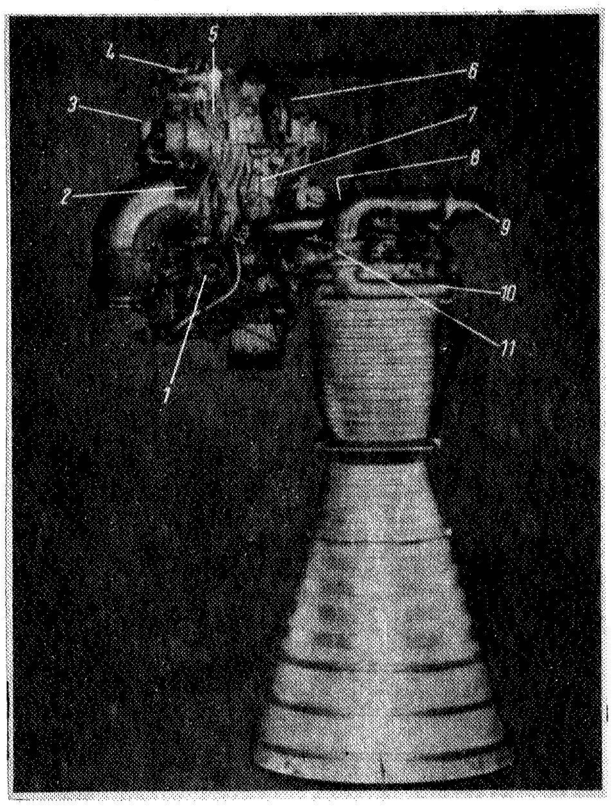

Fig.12 Power Plant of the First Stage for ELDO (Rolls Royce)
1 - Gas producer; 2 - Turbine unit; 3 - Relay module;
4 - Compressed air connection; 5 - Fuel pump; 6 - LOX pump;
7 - Gear casing; 8 - Main LOX line; 9 - Main fuel line;
10 - Injection line for fuel; 11 - Main valve for fuel.

Figure 12 shows an individual power plant. The pumps for the fuel and the liquid oxygen are shown in the upper left portion. Below this is the turbine and, farther down, the gas producer generating the propulsive gases for the turbine.

Installation of the engine into the airframe of the first stage is illustrated in Fig.13. To the left, the nozzles of the main power plants are shown, while the exit ports for the exhaust gases of the turbines used for driving the fuel pumps, are on the right. By swiveling the engines in the same sense, the

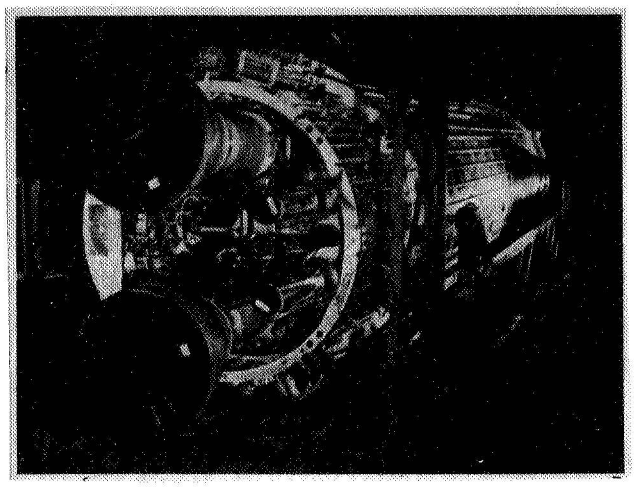

Fig.13 First Stage for the ELDO, Engine Installation

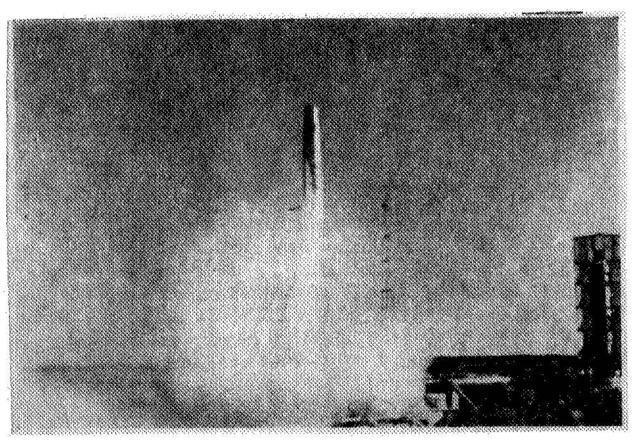

Fig.14 Launching of the First "ELDO A" stage in Woomera, Australia

direction of thrust and thus the direction of the flight path can be varied. By turning the engines about their common transverse axis in opposite direction, the system can be rotated about its longitudinal axis during flight.

The airframe, i.e., the stressed structure of the first stage, housing the kerosene and liquid oxygen tanks as well as the engines themselves, is being manufactured at the Hawker Siddeley Dynamics.

Until now, in accordance with the ELDO program, three launchings of the first stage have been made according to schedule, all of which were successful. Figure 14 shows one of these launchings.

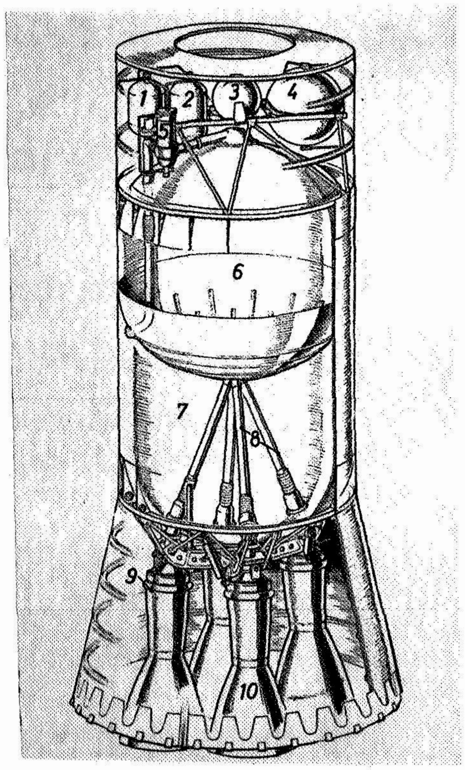

Fig.15 Sketch of the Second Stage for ELDO
1 - Tank for reserve fuel; 2 - Tank for reserve oxidizer; 3 - Helium tank; 4 - Cooling-water tank; 5 - Gas producer for pressure feed; 6 - Oxidizer tank; 7 - Fuel tank; 8 - Oxidizer lines to the combustion chambers; 9 - Fuel feed; 10 - Four swivable thrusters.

The second stage of the launch vehicle is being developed on the basis of experience gained with the "Véronique" series in France (Fig.15). As fuel, asym. dimethylhydrazine (ADMH) and, as oxidizer, nitrogen tetroxide (N_2O_4) are used, carried in tanks installed above the engines. The total thrust of the second stage, of about 28 tons, is produced by four engines. Feeding of the propellants to the engines from the tanks (6) and (7) takes place by compressed gas. This gas is generated in the system visible at the upper portion of the stage. Helium, stored under pressure in the tank (3), is used for transporting both fuel and oxidizer from the tanks (1) and (2) to the gas generator (5). The combustion gases produced in the gas generator are cooled by injection of water from the tank (4) and then fed to the main propellant tanks in the form of pressure gas. The four engines (10), in this stage, can be swiveled in pairs about one axis each, so as to vary the direction of thrust and to rotate the system about its longitudinal axis in flight.

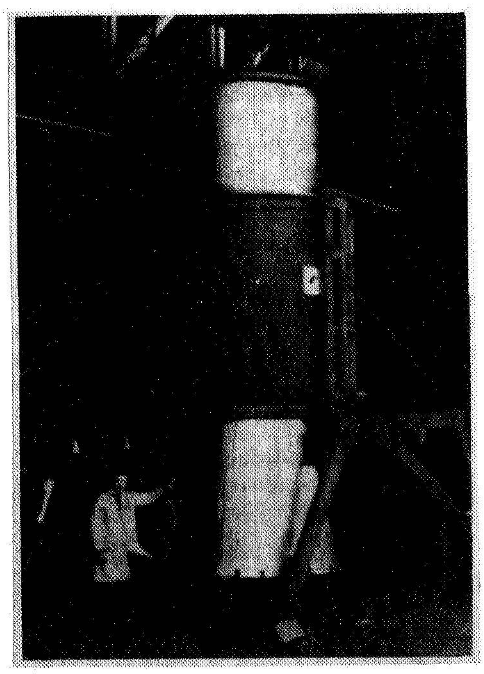

Fig.16 Full-Scale Model of the Second Stage for ELDO (France)

Figure 16, showing a full-scale model of the second stage gives an impression of the dimensions of the stage.

The stand tests of the second stage are performed at the facilities of the Laboratoire des Recherches Balistiques et Aérodynamiques (Laboratory of Ballistic and Aerodynamic Research) in Vernon, France. A combustion test with the four engines of the stage, on the test stands of this Laboratory, is shown in Fig.17. After the testing, test launchings of the second stage are scheduled from a launch pad in Colomb-Béchar, North Africa.

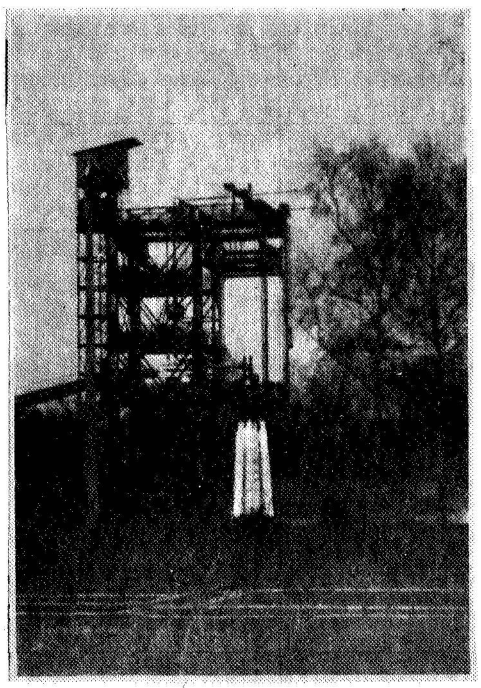

Fig.17 Engine System of the Second Stage on the Test Stand (LRBA, France)

The development and construction of the third stage is done in the German Federal Republic, by a Cooperative formed of the Entwicklungsring Nord (Development Combine, North) and the Bölkow GmbH. The Entwicklungsring Nord combines the Vereinigte Flugtechnische Werke (United Aeronautics Works) and the Hamburger /8 Flugzeugbau (Hamburg Aircraft Construction Co.).

A full-scale model of the third stage is shown in Fig.18. The thrust of 2.25 tons is produced in the third stage by a central power plant. For coarse control of the stage about the two transverse axes in flight, the main engine can be swiveled about two mutually perpendicular axes. The fine control about the same axes as well as the rotation of the stage about the longitudinal axis

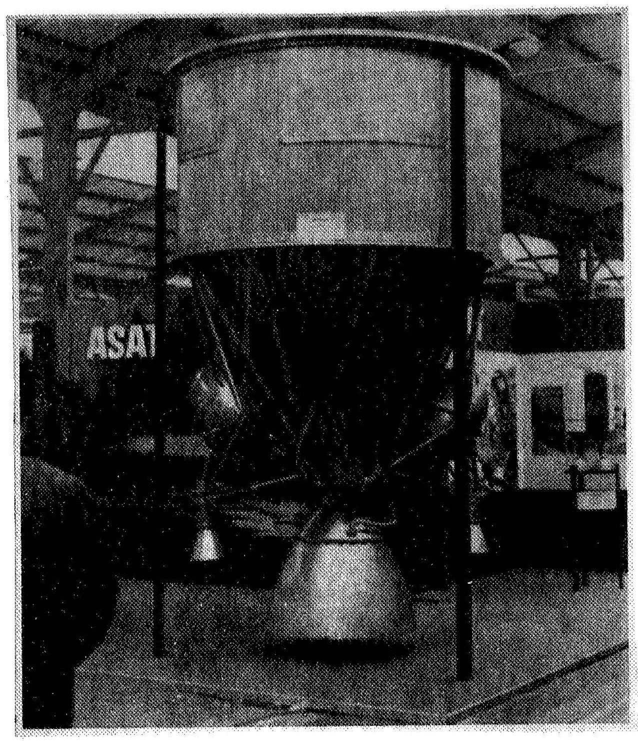

Fig.18 Full-Scale Model of the Third Stage for ELDO (ERNO)

proceed over the two sustainer engines, mounted to the outside on gimbals and exerting a thrust of about 40 kp*. If necessary, the sustainer engines are able to continue operating after combustion cutoff of the main engine and thus permit a transfer at reduced payload, to an orbit higher than the scheduled 550 km. The large spherical tank above the engines, whose lower portion is visible in the photograph, is partitioned and thus can house both fuel and oxidizer. These are fed to the engines by helium compressed to 300 atm and carried in small elliptical tanks, installed to the right and left below the main tank. Tanks

* kp = kilopond = kilogram = kg.

as well as engines are connected with the main spar which also carries the satellite platform. During flight, the entire third stage, together with the satellite, is covered with a nose fairing which will fall away after ignition of the second stage.

The fabrication of the spherical fuel tank of the third stage presents a difficult manufacturing problem. The material of the tank must not only have high mechanical strength at low weight but must also be sufficiently resistant to the corrosive effect of the propellants. For this reason, titanium sheeting of 1.2 mm thickness with a tensile strength of 100 kg/mm^2, at a specific weight

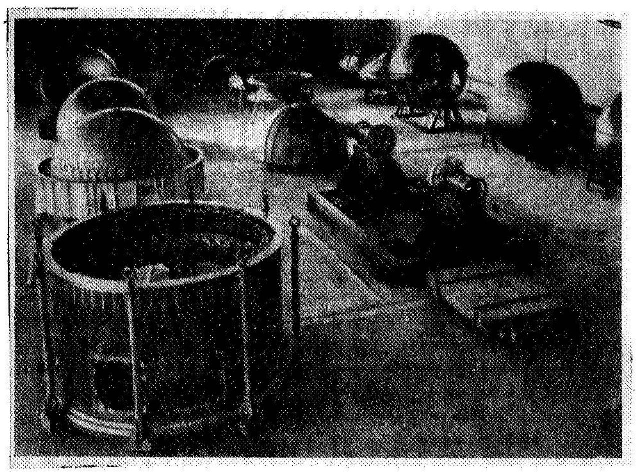

Fig.19 Airframe and Propellant Tanks of the Third Stage for the European Launch Vehicle (Vereinigte Flugtechnische Werke GmbH).

of 4.85 gm/cm^3, is used. Figure 19 shows the spherical tank, of a diameter of 1.72 m, in various stages of manufacture. Farther in the background, to the right, the partition of the tank, manufactured by explosive molding, can be seen. To the left front, the hull of the upper portion is visible which, during burn of the first or second stage, serves for transmitting the thrust produced by these stages to the still inoperative third stage. Here again, sheet

titanium is used. The body itself consists of smooth sheeting of 0.2 mm thickness, to which, for absorbing the compressive forces, corrugated sheeting of /9
0.1 mm thickness is roll-seam-welded.

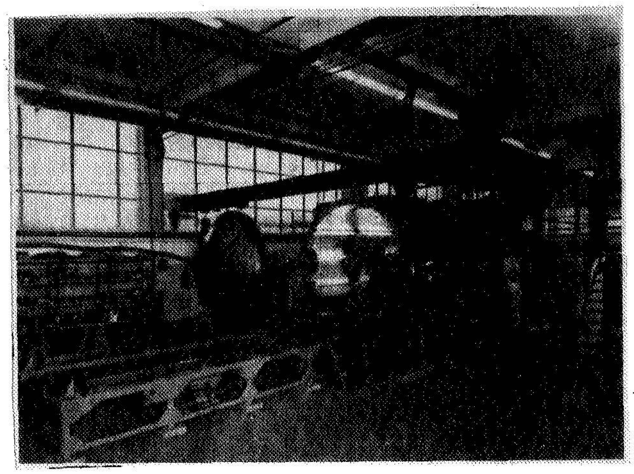

Fig.20 Vacuum Tank of an Electron-Beam Welding Unit (Vereinigte Flugtechnische Werke GmbH).

Previously, the individual parts of the tank had been joined by protective gas welding. In the future, electron-beam welding will be used. This method permits an almost stress-free welding, since the electron beam only heats a narrowly defined zone of the material. Figure 20 shows the electron-beam welding unit of the Steigerwald Co., erected recently in the Vereinigte Flugtechnische Werke in Bremen. The photograph shows the six-meter long vacuum tank, to which the electron gun is mounted. This gun operates at a voltage of 150 kv and has a power consumption of 3 kw. After inserting the workpiece, the tank is closed with the cover, suspended from the trolley at the left, and can then be evacuated to 10^{-4} torr. For radiation protection, the vacuum tank is lined with a 4 mm lead coating. Quartz windows and a television camera mounted inside the tank permit observation of the workpiece during the welding.

Test stands for testing the engines and the entire third stage, under ground conditions, are being erected on the test field of the German Aeronautics and Space Research Organization (DFL). One of these test stands is shown in Fig.21. This stand permits simultaneous experimental runs of the main engine and of the sustainer engines, in which case the engines can be fed with propellant either from stationary installations or from the tanks of the third stage, over the onboard propellant system. /10

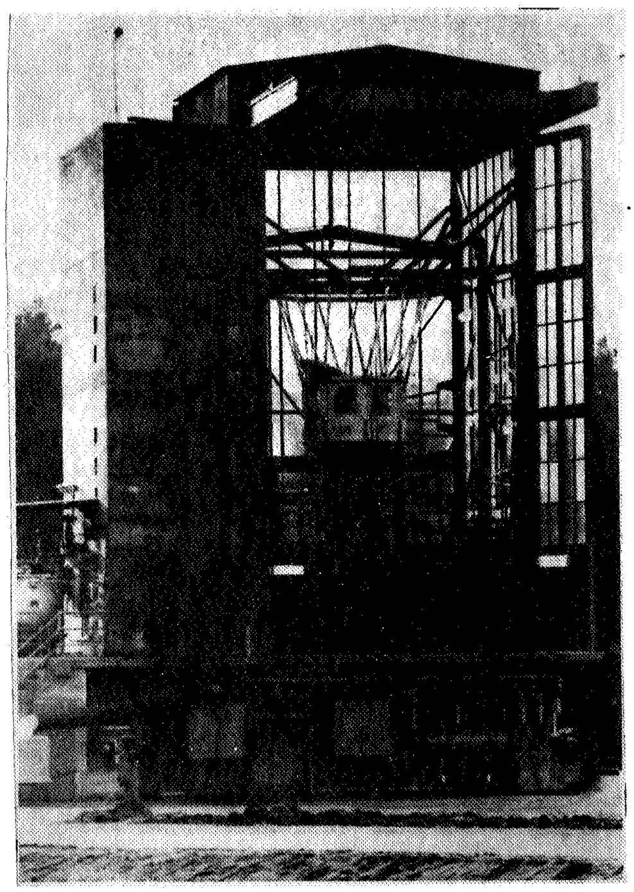

Fig.21 Vertical Test Stand for Engine Tests on Full-Scale Units (DFL, Trauen)

In launching the entire system, the engines of the third stage cut in only at an altitude of about 200 km. Therefore, tests must be made to determine whether the engines will satisfactorily ignite and operate without vibration at the low pressures corresponding to such altitudes. For this purpose, special altitude test stands are required. Such a test bed, as erected in Lampoldshausen near Stuttgart at the German Aeronautics and Space Research Organization (DVL), is shown in Fig.22. In the background, the building of the test stand

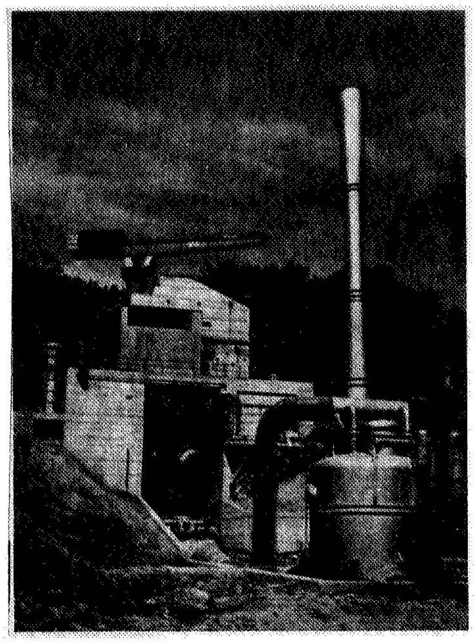

Fig.22 Test Stand for Altitude Tests of Rocket Stages (DVL, Lampoldshausen).

itself is visible, with the altitude chamber for the test object mounted to the top. This chamber, and the connecting duct, are evacuated to a very low pressure. The duct, at the beginning of the test, is closed off by a membrane which is destroyed when struck by the hot gases of the rocket. To simulate the low pressure of actual flight at the exhaust nozzle of the rocket engine during burn, the rocket exhaust gases are removed by means of two ejectors. The hot gases are cooled by water injection. The large boiler in the foreground of the photograph contains one of the coolers. At the top, a large pipe protrudes which houses the second ejector.

The third stage has the function of inserting the satellite into the desired orbit. For this, the trajectory of the third stage, especially in the terminal phase of the flight, must be carefully modulated. To check whether the above-described system of thrusters and the connected attitude control system of the third stage satisfactorily meet this requirement, the Bölkow Co. developed a dynamic test stand on which the original structural parts of the attitude control system for the sustainer engines are being tested (Fig.23). During the

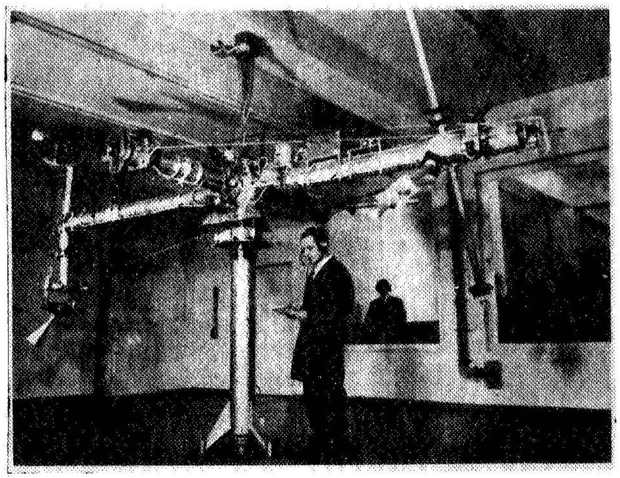

Fig.23 Dynamic Test Stand for Attitude Control of the Third Stage (Bölkow GmbH)

tests, a branched piping system of several meter length and approximately 150 kg weight is supported on a frictionless air bearing, which is under a pressure of approximately 7 atm. With respect to weight and moment of inertia, this pipe system can be conceived as a model of the third stage. Swivable compressed-air nozzles along the principal axes of the connecting link assembly permit the generation of perturbation processes which must be automatically corrected by the attitude control system. In the vertical pipe, the compressed air is supplied to the gas bearing and to the nozzles, as well as to the trueto-scale sustaining engines.

The third stage carries the satellite. The configuration, structure, and equipment of the satellite will depend on the individual mission program. The development and construction of a preliminary series of experimental satellites, including the electronic equipment, is being conducted under Italian management.

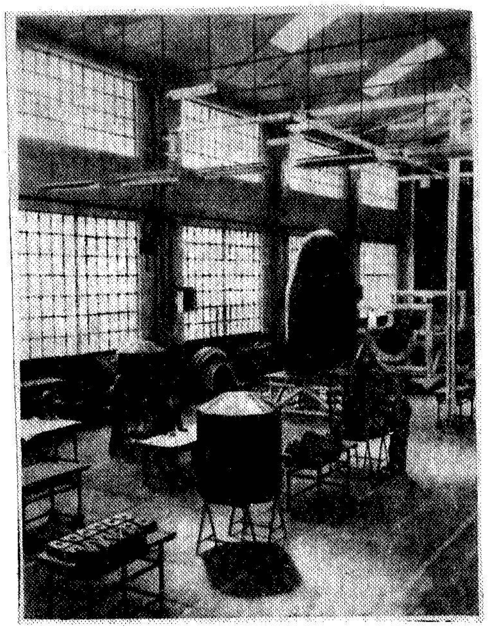

Fig.24 Manufacture of Nose Cone and Experimental Satellites for "Europa I" (Fiat, Italy)

The manufacture of the nose cone of the "Europa I", as the launch vehicle in the development stage has been named, as well as of the first experimental satellites has been assigned to the FIAT plant in Turin. Figure 24 gives a general view over the assembly hall, showing the nose cone of the system and several satellites.

Before launching the satellites together with instrumentation and standby equipment for power supply, data transmission, stabilization, etc. into /11 space, ground tests are necessary. For this, testing facilities of various types are used, erected at the Centro Ricerche Aerospaziali (Aerospace Research

Center; CRA) near Rome. These facilities also include a system for simulation of space environment, shown in Fig.25. The space simulator has a diameter and

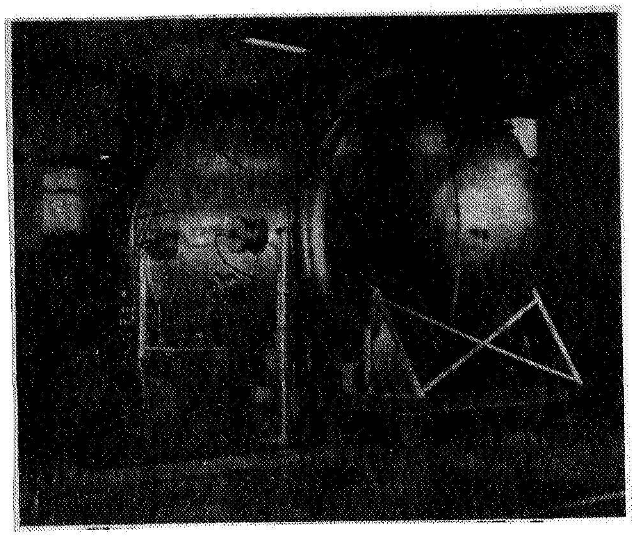

Fig.25 Space Simulator, Overall View
(Centro Ricerche Aerospaziali, Rome).

a length of 3.30 m. The vacuum system consists of a forevacuum pumping unit and three diffusion pumps, connected in parallel. Inside the simulator, a cryopump is erected for simulating the low-temperature background of space. This cryopump consists of a cage formed by finned pipes. The inner surface is

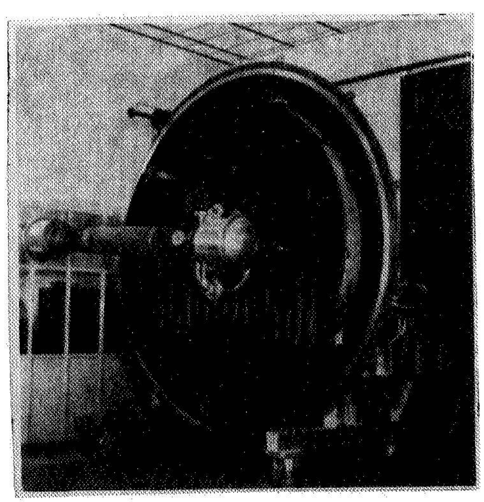

Fig.26 Space Simulator (CRA), Motion Simulator for Satellites

blackened so as to act as a black body. For cooling, liquid nitrogen is used.

Solar simulation is obtained by means of xenon lamps. The motion simulator, mounted in the chamber across from the solar simulator, is shown in Fig.26. This device permits turning the test object about two axes. Both axes are provided with collector rings for the transmission of test data and for current supply to the test object. The collector rings are encapsulated so that they will not operate in the high vacuum, and thus have only negligible interference due to contact resistance.

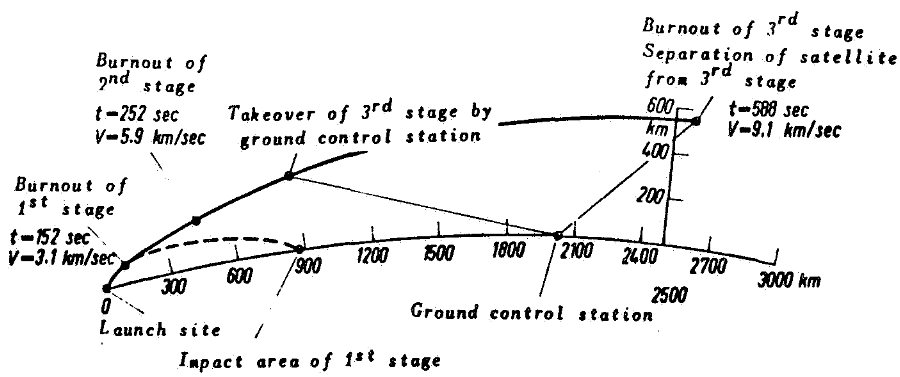

Fig.27 Trajectory for ELDO Launch Vehicle, Launch Site at Woomera, Australia

The space simulator, shown here, permits simulation of widely differing thermal influences and phenomena, such as the reproduction of the entire heating process during one orbital revolution.

The success on blastoff of a space vehicle depends decisively on whether it is possible to guide the flight path, from the time of liftoff to insertion into orbit, in accordance with the optimally determined data. For a circular orbit around the earth, at an altitude of 550 km, the characteristic values of the flight path are plotted in Fig.27.

After a burn of the first stage of 152 sec, the system should have reached an altitude of about 70 km and a velocity of approx. 3.1 km/sec. After separation of the first stage, the second stage is to boost the system - after a flight time of 252 sec - to an altitude of approximately 200 km and to impart a velocity of about 5.9 km/sec to the unit. After this, the third stage takes over the propulsion. With this stage, after about 590 sec flight time, the satellite is to be brought to the desired orbital height of 550 km and to a velocity of about 9.1 km/sec. Here, it is of decisive importance to have the flight path parallel to the earth's surface and to adjust the orbital velocity to a value corresponding to the altitude in question, at the instant of burnout of the third stage. To reach this goal, an accurate orbital guidance of the launch system, from liftoff to insertion of the satellite into circular orbit, is required.

The characteristic data of the system flight path during ascent include altitude, acceleration, and velocity. These quantities are plotted in Fig.28 against time. The acceleration b is 0.3 g on blastoff and, because of the /12

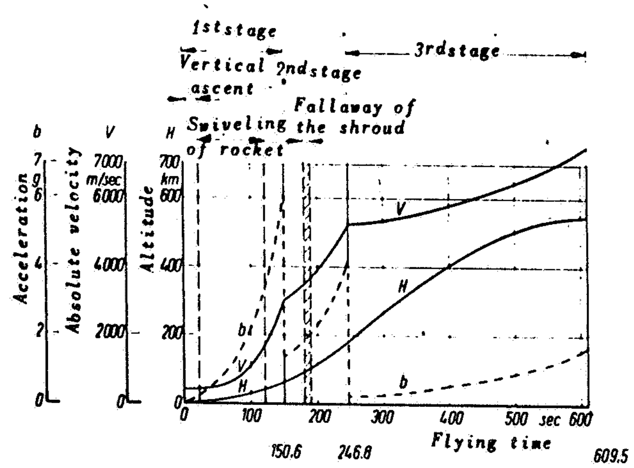

Fig.28 Flight Diagram for the ELDO Launch Vehicle
(Low Circular Orbit)

decrease in weight of the system resulting from propellant consumption, increases to 6.5 g up to burnout of the first stage. Initially, the second stage imparts an acceleration of 1.5 g to the remainder of the system, which increases to 4.3 g up to combustion cutoff. For the third stage, the corresponding values are 0.2 g and 1.6 g. The decrease in the acceleration maxima, from the first to the third stage, expresses the optimizing of the rocket system. With respect to the velocity slope, it must be considered that the system, due to the earth's rotation, is imparted a horizontal velocity of 405 m/sec already on liftoff.

The trajectory of the vehicle is determined by the direction of the engine thrust or by the position of the longitudinal axis of the vehicle, since both directions coincide if the control motions of the engines are disregarded for the time being. Consequently, if all other conditions are known, the trajectory can be programed by coordinating a certain instant of the flight with a certain

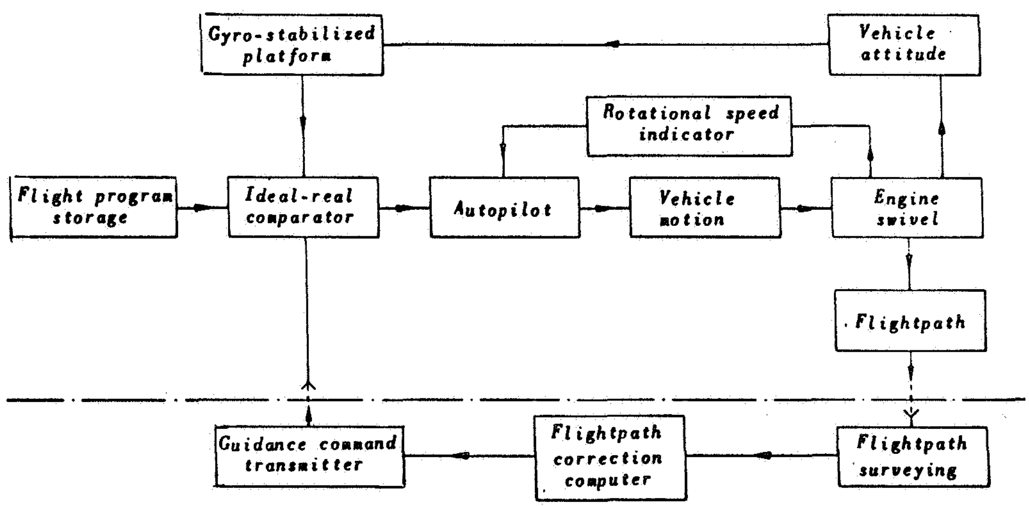

Fig.29 Block Diagram for Trajectory Guidance of ELDO Launch Vehicles

direction of the longitudinal axis of the vehicle relative to a given reference system (Fig.29). This coordination of desired longitudinal inclination of the vehicle with the time of flight is fed to a flight program memory. The actual attitude of the vehicle is measured by means of a gyro-stabilized platform and compared with the ideal values furnished by the flight program memory. The measured deviations are converted by the autopilot into commands for the thrusters of the engines which, by changing their direction of thrust, produce a rotation of the flying body. In addition to this rotation, which is detected by the gyro-stabilized platform, the rotational velocities are measured by suitable gyros and fed back to the autopilots.

Aside from the vehicle rotation, the configuration of the trajectory also depends on the thrust of the engines and - during the initial flight sector - on the state of the atmosphere. If these values deviate from the precalculated data, deviations will occur between the real and the desired flight path. For this reason, the real trajectory is measured by the ground station, for control purposes. An electronic computer is used for furnishing the necessary corrections. Over a guidance command transmitter, these corrections are superposed to the commands furnished by the flight program storage. These check tests are of special importance for the terminal sector of the flight path of the system, during which propulsion is taken over by the third stage; these check tests are of decisive importance for satisfactory insertion into orbit of the satellite.

The above-sketched trajectory guidance system, so far as it is housed within the launch vehicle, will be developed and built in Holland in cooperation with the German Federal Republic.

A model of the system, used for surveying the flight path from the ground, for calculating the necessary midcourse corrections, and for transmitting the guidance commands to the flying system, is shown in Fig.30. The parabolic antennas A1, A2, and A3, shown in the right foreground, are used pairwise for determining the angles under which position fixing of the vehicle takes place from the ground. These antennas operate on the interferometer system and have a base line of 16 m. The distance between ground and space vehicle is measured over the parabolic dish A5 which simultaneously measures the radial velocity of the flying body. The tangential velocities of the vehicle are interferometrically determined by the antenna pairs A1, A4 and A1, A5 whose base line is 192 m.

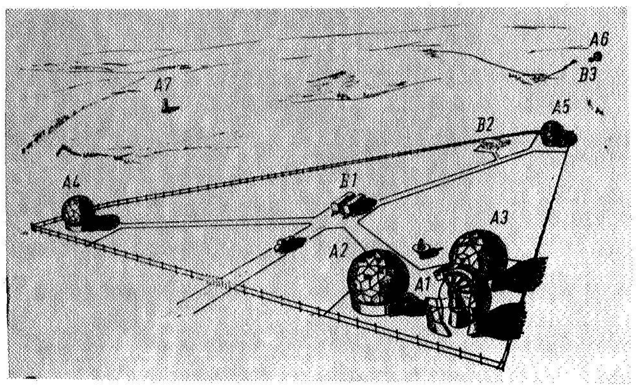

Fig.30 Ground Control Station in Australia (Developed by Belgium)

Fig.31 Parabolic Antenna for ELDO Tracking System, Diameter 4.20 m (MBLE, Belgium)

The station A6 serves for transmitting the commands to the vehicle. The system A7 is used for calibrating the equipment. The building B1 contains the en- /13
tire electronic equipment, including the computer system; the building B2 houses

the power station, while the building B3 is scheduled as the telemetry center. The equipment of all these ground stations is being developed and built by Belgium. The stations will be erected at Cape Gove in Northern Australia, about 650 km East of Darwin.

The parabolic antennas, to be erected in Australia, are being tested at present in Belgium on their standby facilities (Fig.31). The diameter of the parabolic dish of such an antenna is 4.20 m.

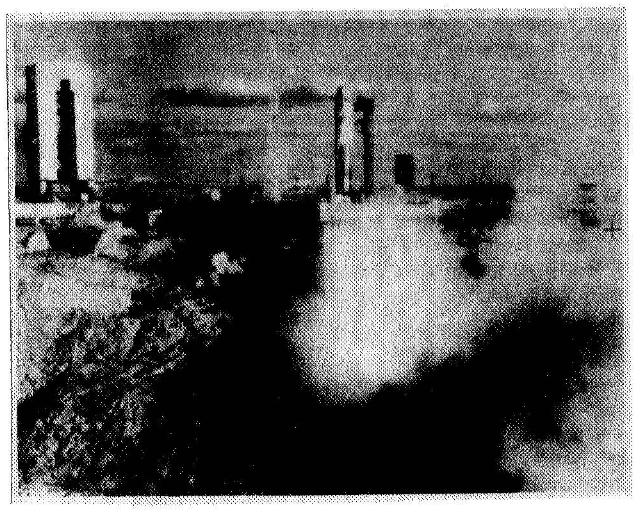

Fig.32 Launch Complex in Woomera, with the First Stage of the "Europa I" (Australia)

During launching of the system, the individual stages must transmit a large number of test data for monitoring satisfactory operation of the individual instruments and for detecting the causes of failure in the case of aborts. In addition, test data from the satellites must be received or commands and messages must be transmitted to them. Italy and Holland are cooperating in designing the necessary telemetry system.

For the above reasons, Woomera in Australia was selected as launch site for the booster system. Figure 32 gives a general view of the launch facilities in

Woomera. The first stage is shown on the launch pad during a static launch test. The hot exhaust gases, mixed with water vapor, are discharged from a lateral orifice below the launch pad, erected at the edge of a steep slope. To the left, somewhat farther back, the gantry scaffold is visible which, during assembly of the launch vehicle, is placed above the launch pad and is shifted backward out of the way before ignition of the engines. Details of this derrick are shown in Fig.33. In this photograph, the "Europa I" is just about being lifted from the horizontal into the vertical position. The first launching of a complete launch vehicle of the ELDO is planned for 1967.

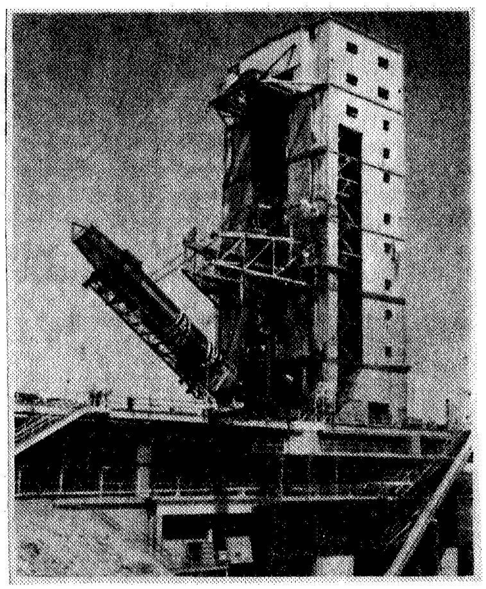

Fig.33 Scaffold in Woomera with the First Stage of the "Europa I" (Australia)

3.3 Future Program of the ELDO

Naturally, at the beginning of the work, main emphasis within the ELDO is placed on proper start-up of the described initial program. This phase of the work has come to a certain conclusion at present, so that continuation of the program can be begun. This program has the purpose of increasing the efficiency of the present system and thus to broaden its application possibilities. The /14 ways and means under consideration at present are sketched in Table 3. It should be mentioned specifically that the data mentioned here constitute only preliminary calculations which, in part, still require detailed checking.

TABLE 3

EFFICIENCY INCREASE OF THE ELDO ROCKET

Designation	Characteristics	Estimated Efficiency			
		Polar Orbit		Equatorial Orbit	
		Altitude (km)	Payload (kg)	Altitude (km)	Payload (kg)
ELDO-A/S	ELDO-A (Europa I) with apogee rocket	10,400	150	-	-
ELDO-B1	Two-stage, upper stage with liquid H_2-O_2	500	1500	500	1800
ELDO-B1/S	With apogee rocket	10,400	550	36,700	350
ELDO-B2	Three-stage, both upper stages with liquid H_2-O_2	550	3000	36,700	1000

The efficiency of the launch vehicle system of the initial program can be improved for greater altitudes, by using an apogee rocket (ELDO-A/S). On burn-out of the third stage, the remaining vehicle enters an elliptical ballistic trajectory at whose apogee a small rocket is ignited. This will then insert the satellite into a circular orbit, with the height of the apogee. A considerable increase in performance can be obtained by changing from the present medium-energy propellants to high-energy propellants such as liquid hydrogen plus liquid oxygen. As a first step, a two-stage system has been considered for the ELDO-B1. Possibly, this will be followed later by a three-stage system, ELDO-B2. In the latter, the same engine is to be used in the third stage as in the upper stage of the ELDO-B1, while the second stage of the ELDO-B2 would be propelled by four engine clusters of the same type. In the ELDO-B1, the use of an apogee rocket also had been considered, with which synchronous orbits, of interest for communications satellites, can be obtained on blastoff from an equatorial base, as in the ELDO-B2. Of the preliminary work, performed for engines with high-energy propellants, a typical example is the H_2/O_2 engine developed by the Bölkow Co., with a thrust of 30 kp (Fig.34). The engine has already been tested under ground conditions with liquid hydrogen/liquid oxygen. A prototype was tested under simulated altitude conditions, with a corresponding nozzle extension.

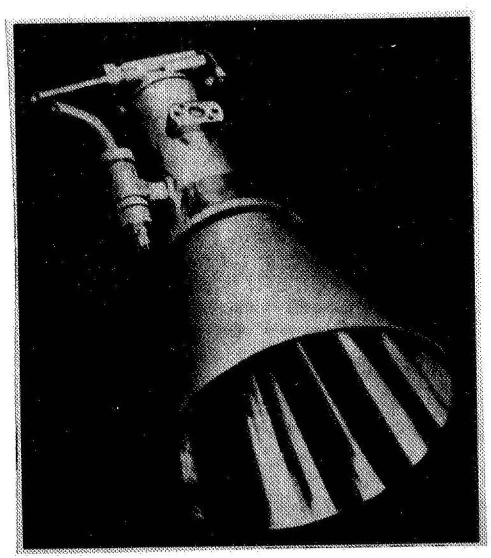

Fig.34 High-Power Engine (Bölkow GmbH)

The equatorial orbits, shown in Table 3 for the ELDO-B1 and B2 systems, presuppose that by that time a launch base near the equator will be available. Possibilities for this are under study. France has offered the use of her launch facilities, which are being erected in Guayana (South America) within the scope of the French National Program and which then would have to be suitably enlarged. The possibility of launching from Northern Australia is also under consideration. Another interesting suggestion is an Italian project, to erect an island in the ocean as a launching base at a suitable location. This method has already been used by Italy in the Santa-Rita platform. Figure 35 shows this platform during work in March 1964, located in front of the Kenya coast in the Indian Ocean. The water depth is relatively shallow there, and the three pedestals of the platform rest directly on the bottom of the sea.

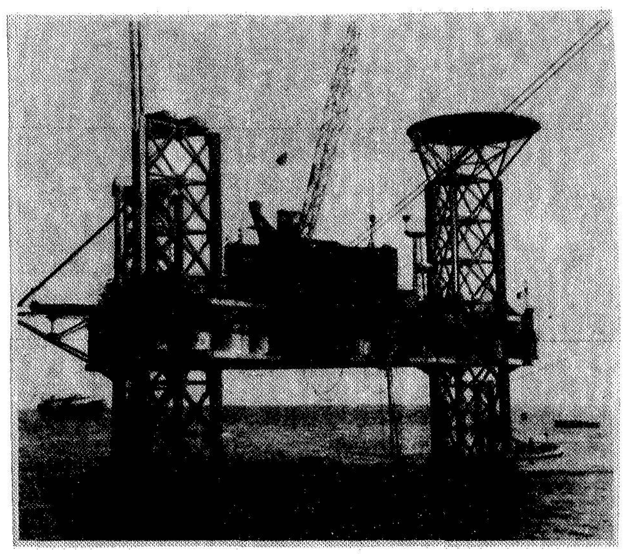

Fig.35 Santa-Rita Platform (Italy)

In the further development of the ELDO launch system, its use for communications satellites has been contemplated. It is known that the USA at present /15 is developing a system of communications satellites which already is working successfully. This system, in accordance with the requirements of the USA, primarily will establish connection from the USA in an East-West or North-South direction. For the European trade, North-South connections (for example, Europe-Africa) or diagonal connections (for example, Europe-Australia or Europe-

South America) as well as connections between Europe and Eastern Asia will become of considerable importance in the future. Therefore, it would be desirable to supplement the American system of communications satellites by a European system that could cooperate with the American system.

Because of the great significance that communications by means of satellites, as a supplement to existing cable connections, will attain in worldwide communication, various communication companies and public utilities of the USA have signed in August 1964, with most of the West European nations as well as with Australia and Japan, an agreement on temporary regulation for a commercial worldwide satellite communications system and formed the Interim Communication Satellite Committee (ICSC). The USA is participating in this with 61%. The European partners of the ICSC, to safeguard their interest, have formed the Conférence Européenne des Télécommunications Spatiales (European Conference of Space Communications; CETS). Coordinated work is scheduled here, to be preceded by corresponding preliminary work on a national basis.

In addition to the plans for continuation of the present ELDO program, Research and Development work is in progress within the scope of national programs of the individual member nations, on vital components of future space vehicles. This includes electronic structural elements of small bulk, low weight, and low power requirement, at high reliability; high-quality navigation instruments, new processes for power generation and power conversion, novel propulsion units, and others. As a typical example for investigations in the two latter fields, Fig.36 shows an experimental installation with which, in the Institute for Plasma Physics of the Nuclear Research Station in Jülich, systematic research is being conducted on the acceleration of plasma beams. In this installation, an electrodeless plasma acceleration is produced by an electromagnetic wave. At the left, the gas enters a glass tube which is kept under vacuum. The glass tube is surrounded by the coils of a cascade conductor. In this conductor, an electromagnetic traveling wave is generated, which ionizes, heats, and accelerates the gas. The traveling wave acts here as a magnetic piston. In the experiments, velocities of the plasma beam up to 100 km/sec have been measured, although only for the short time of 10 μ sec. Since modifications of such accelerators are in question for plasma rocket propulsion, this particular work is done at the Nuclear Research Station in Jülich, in close cooperation with the DVL.

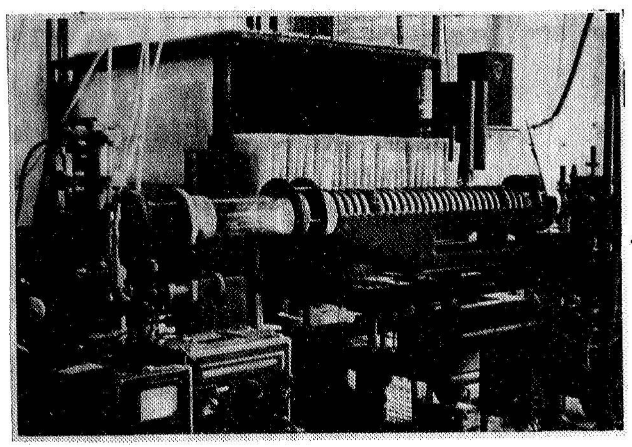

Fig.36 Magnetohydrodynamic Propulsion Unit (Institute for Plasma Physics of the Nuclear Research Station, Jülich)

At present, numerous agencies throughout the world are studying the various possibilities of producing high-velocity plasma beams; however, this point will not be further discussed here.

4. Political Significance of Space Flight for Europe

Finally, some remarks should be made as to the political significance of space flight, as resulting from the cooperation of the ESRO and ELDO.

Even the tasks of space research and space flight, mentioned here and intentionally excluding manned space flight, can be successfully handled in Europe only if a number of nations cooperate. The ESRO constitutes such a cooperative for common solution of scientific problems; here, scientists of different nations are given the opportunity of close cooperation. The ELDO has the function of common development and construction of a large industrial product, namely, a satellite launch system, in which failure of even the smallest part can jeopardize the entire success. Consequently, the cooperation of the individual member nations of the ELDO must be extremely close. The work, both in the ESRO and in the ELDO, thus represents an important contribution to a tighter union of Europe.

Several scientific and economic applications of space flight exceed the European scope. Therefore, cooperation with the USA is indispensable. However, if Europe were able to produce important results on its own in the fields in question, the USA would no doubt welcome it as a valued partner in common work. The work of the European organizations in the field of space travel is intended to serve only peaceful purposes. Hopefully, our common effort in space travel will lead to success and thus contribute to a strengthening of international cooperation for safeguarding the peace.

Summary

European cooperation in the field of space research and aerospace engineering is chiefly carried out in the European Space Research Organization (ESRO) as well as in the European Launcher Development Organization (ELDO). The programs, structure, and activity of these organizations are discussed in detail.

Today, economic application of aerospace engineering is mainly centered on

communications satellites. In Europe, preparatory work is in progress for /16 studying the optimum participation of European nations in the system of communications satellites suggested by the USA.

In connection with the activity within the European organizations, national programs for space research and aerospace engineering are in progress in the various European nations.

Translated for the National Aeronautics and Space Administration by the O.W.Leibiger Research Laboratories, Inc.